Answers to leftover chat room questions from *Larry Young*'s Seedling Seminar presentation, February 25, 2014

Bill Fredericks: Did you all consider other vehicle configurations that achieve better L/D in order to reduce the energy required to fly the mission?

Larry Young: First of all, I have been a tiltrotor-guy all my career but even I have to admit that tiltrotors are not a fit for every mission.

The final report deliverable, which will also be made into a NASA TM, will be made publicly available and will have some discussion of alternate configurations --including some more exotic than tilt rotors, tilt wings, ducted-fan/powered-lift aircraft -- but this will be relatively brief and will be provided as more of an introduction to the greater design space of electric VTOL vehicles, modular, and distributed-propulsion rotorcraft. Some of these concepts are novel and some are revisiting of concepts from the past.

However, there were very compelling reasons for considering conventional helicopter configurations for the study, with the bulk of work on 30 passenger tandem helicopters.

First, design heritage.

a. Why try convincing your target audience that not only rotorcraft with electric propulsion is a serious research area to pursue but, in addition to that, some novel aircraft configuration is the best of all electric vehicles to study? That was a bridge too far for this study, particularly as the focus was not just on aircraft design but on systems analysis assessments of a vertical lift aerial public transportation system.

b. The conceptual design tools used during this study could be considered to be well-validated against conventional rotorcraft configurations. Such tools become more problematic with the introduction of more exotic vehicle configurations.

C. A very preliminary set of acoustic calculations were made in this

study because of the importance of community acceptance for an urban aerial transportation system. There are publicly available data report for the Boeing Vertol 234 which, conveniently, is approximately the same size of vehicle as the set of tandem helicopters studied in the Hopper study -- and, in the case of future work beyond this study, FAA-accepted software tools such as INM that include the BV234 in their databases could be applied to make far more detailed and comprehensive noise studies.

D. Much, though not all, of NASA rotary-wing research into swashplateless rotors, active rotor control, active flow control, and other technologies have been directed to conventional helicopters. That doesn't mean that such technologies can't be applied to tilt rotor aircraft or other more exotic rotorcraft configurations but additional work to validate such technologies against other aircraft configurations would have to be performed.

Second, being pragmatic in terms of reasonable expectations of seeing some form of the Hopper vehicle/network being realized in the circa 2030 or 2035 time frame.

A. A clean sheet design might not be feasible to meet the study's target date. Instead, to minimize development time and development risk, it might instead be far more feasible to consider heavily modified variants of existing rotorcraft -- both for technology demonstrators as well as possible production vehicles. For example, over the past couple of years Columbia Helicopters has been purchasing "retired" CH-46's and CH-47's for future retrofitting for commercial applications. A similar path might be taken to one day realize a Hopper vehicle/network.

B. Reducing the vehicle development time to a minimum by developing a variant of an existing aircraft versus a clean-sheet design allows the possibility of injecting newer, higher risk technologies into things like active rotor control, active flow control, etc. so as to address passenger/community acceptance issues such as noise, vibration, etc.

C. Continuing the idea of one possible approach to the realization of Hopper is a variant of an existing vehicle is that it also potentially

allows more development/risk-adoption for well-thought-out propulsion modularity, which is likely going to be an essential element. Battery swap-out, whether after every flight or after a cycle life of x discharges, can't require tearing apart the aircraft.

Third, design conservatism.

The vehicle performance numbers of a figure-of-merit of 0.5 and an L/De of 4.2 are intentionally conservative. We didn't want to suggest that some technological leap (or leaps) for the vehicle itself was required to make these vehicles a potential reality. We wanted to clearly show that the Hopper mission was potentially achievable in the mid-term time frame and not some far-term sense.

Now counter-arguments can be readily made to some of the above reasoning, but the point to be made here was that there were -- to the study co-investigators at least -- some compelling reasons to adopt the 30 passenger tandem helicopter as the baseline for the study.